

What is claimed is:

1. An image processing apparatus for quantizing image data indicative of a density gradation level of a constituent pixel of an image into a discrete value on the basis of quantization levels of a number smaller than the maximum density gradation level and not smaller than two, the apparatus comprising:

an N-level/M-level quantization circuit for performing an N-level quantization process with the use of  $(N-1)$  N-level quantization thresholds (wherein N is an integer satisfying a relationship of (maximum density gradation level)  $> N \geq 2$ ) or performing an M-level quantization process with the use of  $(M-1)$  M-level quantization thresholds (wherein M is an integer satisfying a relationship of (maximum density gradation level)  $> M > N$ ) for quantization of image data of an object pixel on an N-level basis or on an M-level basis;

an error diffusion circuit for distributing an error generated through the N-level quantization process or the M-level quantization process performed by the N-level/M-level quantization circuit to peripheral pixels yet to be subjected to the N-level quantization process or the M-level quantization process around the object pixel for modification of image data of the peripheral pixels;

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an N-level quantization threshold setting circuit for setting the N-level quantization thresholds to be used in the N-level/M-level quantization circuit in a periodically variable manner; and

a process setting circuit for causing the N-level/M-level quantization circuit to perform the M-level quantization process for pixels adjacent to a pixel corresponding to at least one of a peak point and a saddle point in the periodic variation of the N-level quantization thresholds and causing the N-level/M-level quantization circuit to perform the N-level quantization process for pixels corresponding to the peak point and the saddle point.

2. An image processing apparatus as set forth in claim 1,

wherein the N-level quantization threshold setting circuit sets the N-level quantization thresholds on the basis of a variable threshold matrix having matrix element values defined in a periodically variable manner,

wherein the process setting circuit causes the N-level/M-level quantization circuit to perform the M-level quantization process for a pixel corresponding to a matrix position of a specific matrix element value in the variable threshold matrix.

3. An image processing apparatus as set forth in claim

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1, wherein the process setting circuit comprises a circuit for defining the specific matrix element value on the basis of an average value of image data of pixels within a region of a predetermined size containing the object pixel and pixels around the object pixel.

4. An image processing apparatus as set forth in claim 1, wherein the N-level quantization threshold setting circuit comprises a circuit for variably setting the N-level quantization thresholds in accordance with the image data of the object pixel.

5. An image processing apparatus as set forth in claim 1, further comprising a circuit for variably setting the M-level quantization thresholds to be used in the N-level/M-level quantization circuit in accordance with the image data of the object pixel.

6. An image processing method for quantizing image data indicative of a density gradation level of a constituent pixel of an image into a discrete value on the basis of quantization levels of a number smaller than the maximum density gradation level and not smaller than two, the method comprising the steps of:

quantizing image data of an object pixel on an N-level basis (wherein N is an integer satisfying a relationship of (maximum density gradation level) > N  $\geq$  2) or on an M-level basis (wherein M is an integer

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satisfying a relationship of (maximum density gradation level) > M > N) with the use of (N-1) periodically variable N-level quantization thresholds and (M-1) M-level quantization thresholds by performing an M-level quantization process for pixels adjacent to a pixel corresponding to at least one of a peak point and a saddle point in the periodic variation of the N-level quantization thresholds and performing an N-level quantization process for pixels corresponding to the peak point and the saddle point; and

distributing an error generated through the N-level quantization process or the M-level quantization process to peripheral pixels yet to be subjected to the N-level quantization process or the M-level quantization process around the object pixel for modification of image data of the peripheral pixels.

7. An image processing apparatus for quantizing image data indicative of a density gradation level of a constituent pixel of an image into a discrete value on the basis of quantization levels of a number smaller than the maximum density gradation level and not smaller than two, the apparatus comprising:

a quantization circuit for quantizing image data of an object pixel with the use of a quantization threshold;

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an error calculating circuit for calculating an error generated through the quantization performed by the quantization circuit;

an error diffusion circuit for distributing the error calculated by the error calculating circuit to peripheral pixels yet to be subjected to the quantization around the object pixel for modification of image data of the peripheral pixels;

a threshold setting circuit for setting the quantization threshold to be used in the quantization circuit in a periodically variable manner; and

an error calculation reference value setting circuit for variably setting a reference value to be used for the error calculation in the error calculating circuit.

8. An image processing apparatus as set forth in claim 7, wherein the error calculation reference value setting circuit variably sets the error calculation reference value so that the reference value varies in phase with the variation of the quantization threshold set by the threshold setting circuit.

9. An image processing apparatus as set forth in claim 7, wherein the error calculation reference value setting circuit comprises a circuit for variably setting a variation range of the error calculation reference value

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with respect to the quantization threshold on the basis of the image data of the object pixel or an average value of image data of pixels within a region of a predetermined size containing the object pixel and pixels around the object pixel.

10. An image processing apparatus as set forth in claim 7, wherein the quantization circuit comprises a circuit for variably setting a variation range of the error calculation reference value in accordance with an area separation signal indicative of a type of an image area to which the object pixel belongs.

11. An image processing apparatus as set forth in claim 7,

wherein the quantization circuit comprises an N-level/M-level quantization circuit for performing an N-level quantization process with the use of (N-1) N-level quantization thresholds (wherein N is an integer satisfying a relationship of (maximum density gradation level) > N  $\geq$  2) or performing an M-level quantization process with the use of (M-1) M-level quantization thresholds (wherein M is an integer satisfying a relationship of (maximum density gradation level) > M > N) for quantization of the image data of the object pixel on an N-level basis or on an M-level basis;

wherein the threshold setting circuit comprises

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an N-level quantization threshold setting circuit for setting the N-level quantization thresholds to be used in the N-level/M-level quantization circuit in a periodically variable manner;

the apparatus further comprising a process setting circuit for causing the N-level/M-level quantization circuit to perform the M-level quantization process for pixels adjacent to a pixel corresponding to at least one of a peak point and a saddle point in the periodic variation of the N-level quantization thresholds and causing the N-level/M-level quantization circuit to perform the N-level quantization process for pixels corresponding to the peak point and the saddle point.

12. An image processing apparatus as set forth in claim 11,

wherein the N-level quantization threshold setting circuit sets the N-level quantization thresholds on the basis of a variable threshold matrix having matrix element values defined in a periodically variable manner,

wherein the process setting circuit causes the N-level/M-level quantization circuit to perform the M-level quantization process for a pixel corresponding to a matrix position of a specific matrix element value in the variable threshold matrix.

13. An image processing apparatus as set forth in claim

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11, wherein the process setting circuit comprises a circuit for defining the specific matrix element value on the basis of an average value of image data of pixels within a region of a predetermined size containing the object pixel and pixels around the object pixel.

14. An image processing apparatus as set forth in claim 11, wherein the N-level quantization threshold setting circuit comprises a circuit for variably setting the N-level quantization thresholds in accordance with the image data of the object pixel.

15. An image processing apparatus as set forth in claim 11, further comprising a circuit for variably setting the M-level quantization thresholds to be used in the N-level/M-level quantization circuit in accordance with the image data of the object pixel.

16. An image processing method for quantizing image data indicative of a density gradation level of a constituent pixel of an image into a discrete value on the basis of quantization levels of a number smaller than the maximum density gradation level and not smaller than two, the method comprising the steps of:

quantizing image data of an object pixel with the use of a quantization threshold;

calculating an error generated through the quantization;

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distributing the calculated error to peripheral pixels yet to be subjected to the quantization around the object pixel for modification of image data of the peripheral pixels;

setting the quantization threshold in a periodically variable manner; and

variably setting a reference value for the error calculation.

17. An image processing method as set forth in claim 16, wherein the error calculation reference value is set so as to be variable in phase with the variation of the quantization threshold.

18. An image processing method as set forth in claim 16, wherein the quantization step comprises the step of quantizing the image data of the object pixel on an N-level basis (wherein N is an integer satisfying a relationship of (maximum density gradation level)  $> N \geq 2$ ) or on an M-level basis (wherein M is an integer satisfying a relationship of (maximum density gradation level)  $> M > N$ ) with the use of (N-1) periodically variable N-level quantization thresholds and (M-1) M-level quantization thresholds by performing an M-level quantization process for pixels adjacent to a pixel corresponding to at least one of a peak point and a saddle point in the periodic variation of the N-level quantization thresholds and by

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performing an N-level quantization for pixels  
corresponding to the peak point and the saddle point.

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